To: Tom Henry, region 3 USEPA
From: Michael Paul, PhD and Lei Zheng, PhD
Subject: PA TMDL Endpoints
Date: 10 November 2008

This memo is to respond to a request from USEPA Region 3 to estimate endpoints derived for PA TMDLs if conditional probability based analysis were removed and to discuss issues associated with the incorporation of USGS data from a special study of Chester County Streams.

PA TMDL Endpoints

We were asked by USEPA Region 3 to reconsider the nutrient endpoints that would be recommended to protect aquatic life in the target streams if the conditional probability analysis component of the stressor-response line within the multiple lines of evidence approach was removed. This brief memo describes what the recommended endpoints would be in our professional opinions in the absence of that specific analysis. I will discuss each of the regional endpoints in turn.

PA Piedmont Streams

Pasted below is Table 7 from the original memo (Table 1), "Development of nutrient endpoints for the Northern Piedmont ecoregion of Pennsylvania: TMDL Application". This is a summary of endpoints derived from the separate lines of evidence.

Table 1 - Table 1 from original memo "Development of nutrient endpoints for the Northern Piedmont ecoregion of Pennsylvania: TMDL Application" – Summary of candidate endpoints for each of the analytical approaches discussed.

Approach		TP Endpoint (µg/L)
Reference Approach		**2-37**
	Reference Site 75th Percentile	16-17
	All Sites 25th Percentile	17
	Modeled Reference Expectation	2-37
Stressor-Response		**36-64**
	Conditional Probability – EPT taxa	38
	Conditional Probability - % Clingers	39
	Conditional Probability - % Urban Intolerant	64
	Conditional Probability - Diatoms TSI	36
Other Literature		**13-100**
	USEPA Recommended Regional Criteria	37
	USEPA Regional Criteria Approach – Local Data	40-51
	Algal Growth Saturation	25-50

Nationwide Meta-Study TP-Chlorophyll	21-60
USGS Regional Reference Study	20
USGS National Nutrient Criteria Study	13-20
New England Nutrient Criteria Study	40
Virginia Nutrient Criteria Study	50
New Jersey TDI	25-50
Delaware Criteria	50-100

If one were to eliminate the Conditional Probability line of evidence completely, the weight of evidence still indicates an endpoint of 40 μg/L; the endpoint does not change. If one were to calculate a median value for any values in Table 1 that show a range (e.g., Under Modeled Reference Expectation, the range is 2-37 and the median value of that range is 19.5 using the MS Excel median function) and then take the median of all the resultant values excluding the stressor-response conditional probability line of evidence, the new endpoint would be 38 μg/L. Of course, taking the median values does not apply any specific weight to any line, although it could be argued that the "other literature" line is weighed more since it has more values. So, if one calculates a median for each weight of evidence line based on the multiple values and takes the median of the resulting values, the endpoint is 39 μg/L. Removing the stressor-response line (so using the median value for distribution based line and the median value of other literature), the endpoint is 28 μg/L.

We also calculated change-points using the raw response values for the 4 response metrics used in the Stressor-Response analysis line and using change point analysis as described in the original paper. In this case we do not represent the response variables as conditional probabilities, but rather as raw values. The resulting table is shown below (Table 2).

Table 2 - Table 2 from original memo "Development of nutrient endpoints for the Northern Piedmont ecoregion of Pennsylvania: TMDL Application" – Summary of candidate endpoints for each of the analytical approaches discussed except with raw value Stressor-Response change point analysis instead of conditional probability values.

	Approach	TP Endpoint (μg/L)
Reference Approach		**2-37**
	Reference Site 75th Percentile	16-17
	All Sites 25th Percentile	17
	Modeled Reference Expectation	2-37
Stressor-Response		**13-66**
	EPT taxa	60
	% Clingers	19
	% Urban Intolerant	13
	Diatoms TSI	66
Other Literature		**13-100**
	USEPA Recommended Regional Criteria	37

USEPA Regional Criteria Approach – Local Data	40-51
Algal Growth Saturation	25-50
Nationwide Meta-Study TP-Chlorophyll	21-60
USGS Regional Reference Study	20
USGS National Nutrient Criteria Study	13-20
New England Nutrient Criteria Study	40
Virginia Nutrient Criteria Study	50
New Jersey TDI	25-50
Delaware Criteria	50-100

Once again, taking the median of the ranges and the median of the final values, the resultant endpoint would be 38 μg/L. Also, calculating medians for each line of evidence and taking the median of those 3 values also leads to an endpoint of 39 μg/L.

• Piedmont endpoint would not change by removing the stressor-response line or by using raw response values in the change-point analysis instead of conditional probability based values.

In summary, there is no substantial change in the endpoint arrived at if the stressor-response line is either removed or raw response values are used in the change-point analysis in place of the values represented as conditional probabilities. It is important to note that the "other literature" line includes a combination of field survey as well as experimentally based values. These are discussed in the original document. Therefore, the endpoints derived here are based on a multiple lines of evidence approach that incorporates field based distributions based on reference site conditions, field based stressor-response relationships, and other literature including experimental evidence. All of these lines combined converge on the final recommended endpoint value of 40 μg/L, which is not substantially altered by removing the conditional probability based analysis.

PA Allegheny Streams

The Allegheny endpoints did not rely on a conditional probability based analysis because the stressor-response line could not be generated for reasons explained in the original memo "Development of nutrient endpoints for Allegheny Plateau and Ridge and Valley ecoregions of Pennsylvania: TMDL Application". Therefore, the endpoint would not change from that recommended before: 35 μg/L.

• Allegheny endpoint would not change because it did not rely on conditional probability based analyses.

Table 3 – Table 3 from original memo "Development of nutrient endpoints for Allegheny Plateau and Ridge and Valley ecoregions of Pennsylvania: TMDL Application" - Summary of candidate endpoints for each of the analytical approaches discussed for the Allegheny Plateau.

Approach		TP Endpoint (µg/L)
Reference Approach		**19-36**
	Reference Site 75th Percentile	33-36
	All Sites 25th Percentile	19
Modeled Reference		**8-42**
Stressor-Response		**NA**
Other Literature		**13-100**
	USEPA Recommended Regional Criteria	10
	USEPA Regional Criteria Approach – Local Data	13
	Algal Growth Saturation	25-50
	Nationwide Meta-Study TP-Chlorophyll	21-60
	USGS Regional Reference Study	20
	USGS National Nutrient Criteria Study	13-20

As before, taking median values from each of the lines and applying no weights to any line, the median values generated are 20 µg/L if each median is considered or 25 µg/L if a median is calculated for each line of evidence and the median of those two values is estimated. The original endpoint weighted the reference approach line more and thus recommended a higher concentration for streams of that region.

In summary, there is no substantial change in the endpoint for Allegheny streams because conditional probability based change point analysis was not used. Equally weighting each line would actually result in a lower endpoint. See summary discussion under Piedmont streams above relative to other literature and the completeness of analytical coverage under the multiple lines of evidence approach.

PA Ridge and Valley Streams

In the Ridge and Valley region, stressor-response relationships were also generated and we used conditional probability based change point analysis as one of the lines of evidence (Table 4).

Table 4 – Table 4 from original memo "Development of nutrient endpoints for Allegheny Plateau and Ridge and Valley ecoregions of Pennsylvania: TMDL Application" - Summary of candidate endpoints for each of the analytical approaches discussed for the Ridge and Valley.

Approach		TP Endpoint (μg/L)
Distribution Based		**10-15**
	Reference Site 75th Percentile	13-15
	All Sites 25th Percentile	10
Modeled Reference		**10-15**
Stressor-Response		**14-23**
	MBSS	
	Conditional Probability - Total Taxa	14
	Conditional Probability - EPT Taxa	14
	Conditional Probability - Percent Scrapers	16
	EMAP	
	Conditional Probability - EPT Taxa	19
	Conditional Probability - Ephemeroptera Taxa	19
	Conditional Probability - Trichoptera Taxa	19
	Conditional Probability - Percent Dominant 5 Taxa	23
Other Literature		**13-100**
	USEPA Recommended Regional Criteria	10
	USEPA Regional Criteria Approach – Local Data	13
	Algal Growth Saturation	25-50
	Nationwide Meta-Study TP-Chlorophyll	21-60
	USGS Regional Reference Study	20
	USGS National Nutrient Criteria Study	13-20

Once again, the endpoint recommended for this region was weighted more by the stressor-response line of evidence, which was drawn from change point analysis of conditional probability based response values. The final recommended endpoint for this region was 25 μg/L. A value based on taking medians for each range and then the median of each analysis line would actually be lower - 16 μg/L. Again, if one were to remove the conditional probability based stressor-response line all together, the median of the remaining values would be 14 μg/L. If one were to include stressor-response based values derived from using raw values in the change-point analysis (Table 5), the resulting endpoint

• Ridge and Valley endpoint would change to 16 μg/L by removing the stressor-response line or 20 μg/L by using raw response values in the change-point analysis instead of conditional probability based values using equal weighting of all lines. Using the raw response values and weighting the stressor-line most would result in an endpoint of 25 μg/L, as originally recommended.

would be 20 µg/L.

Table 5 – After Table 4 from original memo "Development of nutrient endpoints for Allegheny Plateau and Ridge and Valley ecoregions of Pennsylvania: TMDL Application" - Summary of candidate endpoints for each of the analytical approaches discussed for the Ridge and Valley except with raw value Stressor-Response change point analysis instead of conditional probability values.

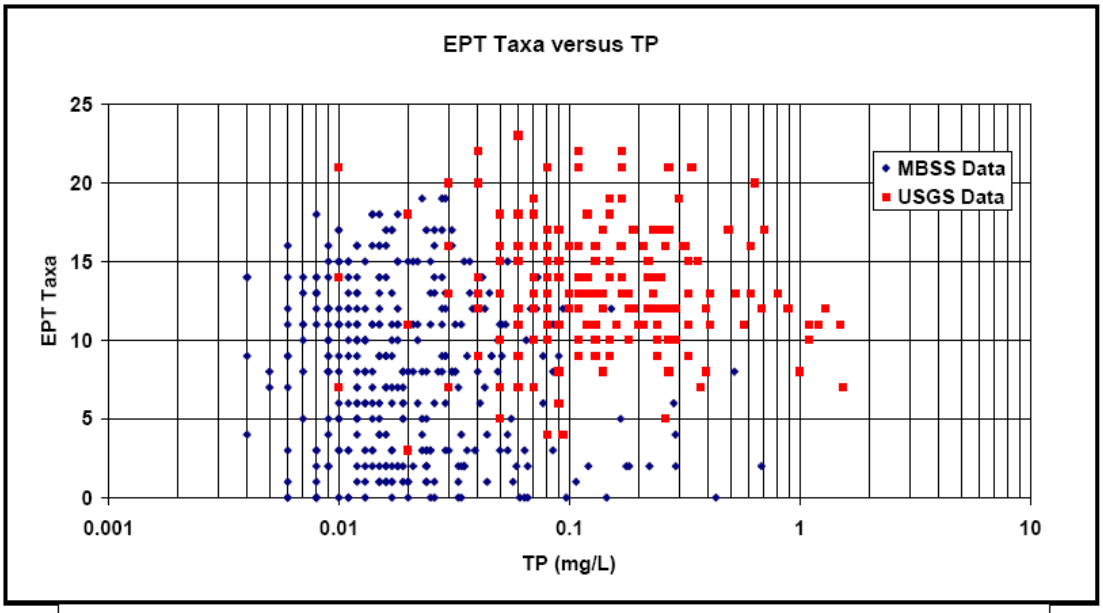
Approach		TP Endpoint (µg/L)
Distribution Based		**10-15**
	Reference Site 75th Percentile	13-15
	All Sites 25th Percentile	10
Modeled Reference		**10-15**
Stressor-Response		**21-28**
	MBSS	
	Total Taxa	21
	EPT Taxa	21
	Percent Scrapers	NS
	EMAP	
	EPT Taxa	30
	Ephemeroptera Taxa	28
	Trichoptera Taxa	NS
	Percent Dominant 5 Taxa	NS
Other Literature		**13-100**
	USEPA Recommended Regional Criteria	10
	USEPA Regional Criteria Approach – Local Data	13
	Algal Growth Saturation	25-50
	Nationwide Meta-Study TP-Chlorophyll	21-60
	USGS Regional Reference Study	20
	USGS National Nutrient Criteria Study	13-20

In summary, removing the stressor-response line based on conditional probability and using equal weighting of the remaining lines would result in a decrease in the endpoint to 16 µg/L or to 20 µg/L if raw value based stressor-response change point analysis were used and equal weighting applied. If the stressor-response line using raw data was weighed more, the endpoint would once again, be 25 µg/L as recommended in the original memo. See summary discussion under Piedmont streams above relative to other literature and the completeness of analytical coverage under the multiple lines of evidence approach.

Validity of the USGS Chester County Study Data Incorporation

We were recently made aware of data collected by the United State Geological Survey as part of a Chester County Water Resources Authority – USGS collaboration from 1980 through the 1990s that may be relevant to this endpoint derivation effort (Rief 1999, 2000, 2002a, 2002b). We were sent a newsletter published by G. Fred Lee (http://www.gfredlee.com/Newsletter/swnewsV11N9.pdf Accessed 11 November, 2008) where the following graph (cited as Hall 2008 personal communication) was presented and an argument made that this shows that there is no relationship between TP and EPT Richness. We were then asked to comment on this analysis and its relevance. We downloaded the 4 reports and all of the relevant raw USGS data from the USGS NWIS database.

Figure 1



The original MBSS data used in the Paul and Zheng (2007) TP endpoint analysis was augmented with USGS data for the following 12 streams: Stony Run near Spring City; Ridley Creek at Goshenville, and at Dutton Mill near West Chester; East Branch Chester Creek at Westtown, and below Goose Creek near West Chester; Middle Branch White Clay Creek at Wickerton; East Branch Big Elk Creek at Elkview; West Branch Big Elk Creek near Oxford; Valley Creek near Atglen; West Branch Brandywine Creek, and East Branch Brandywine Creek at Wawaset; and, Brandywine Creek near Chadds Ford.

from: Hall (2008)

Figure 1 - Figure 1 from Newsletter article "Comments on US EPA's Conditional Probability Approach for Developing Phosphorus Nutrient Criteria" from G. Fred Lee (http://www.gfredlee.com/Newsletter/swnewsV11N9.pdf Accessed 11 November, 2008)

Methodological Differences Relevant to Comparison

There are a number of problems with this application of the USGS data. The first is related to the mixing of MBSS and Chester County USGS data on the same graph. The USGS sampling protocols were completely different from the Maryland Biological Stream Sampling protocols. The USGS sampled 10 rocks from riffle areas only and identified all the individual invertebrates

picked form those rocks. The taxa richness metrics, including EPT richness, was based on an average of 1700 individuals (Rief 2002a). The MBSS, in contrast, used a proportional multi-habitat sampling protocol collecting invertebrates from multiple habitats and only identified 100 individual organisms, from which their richness estimates were made (MBSS 2007). The first comparability is related to habitat sampling. Habitats differ in the composition of taxa that occupy them, a basic concept in ecology (Ricklefs 1990). As a result, different habitat sampling approaches capture different taxa. Therefore, one cannot simply mix data from two distinct sampling protocols that sample different habitats and expect them to be comparable. Second, one of the more basic concepts in ecology is the species-area and species-effort curve concepts. These concepts explain that the number of taxa found (diversity/richness) is a function of the amount of area sampled and/or the number of individuals identified (Ricklefs 1990). Simply put, the more individuals you identify, the more taxa you find and the higher your richness and diversity measures. Because the USGS sampled a different area and counted, on average an order of magnitude more individuals (17 times), they will, by definition, encounter more taxa. Therefore, the comparison made in Figure 1 violates basic ecological principles and is invalid.

Putting aside the dramatic differences in sampling protocol, there are methods for making samples of different size using the same sampling methods comparable. These are called rarefaction methods and are explained in most introductory ecology texts. Assuming for sake of argument that the sampling methods sampled the same habitat, which they clearly did not, we applied a rarefaction technique developed by Dr. Dave Roberts of Utah State University to at least explore how comparable the species richness would be if sample sizes were comparable. This rarefaction method uses a probabilistic resampling procedure to subsample the individuals of a larger sample size down to one of a smaller sample size. We, therefore, subsampled the USGS data down to fixed sample size of 100 individuals to make it comparable to the MBSS sampling effort. We then recalculated the metric responses and replotted the data (Figure 2).

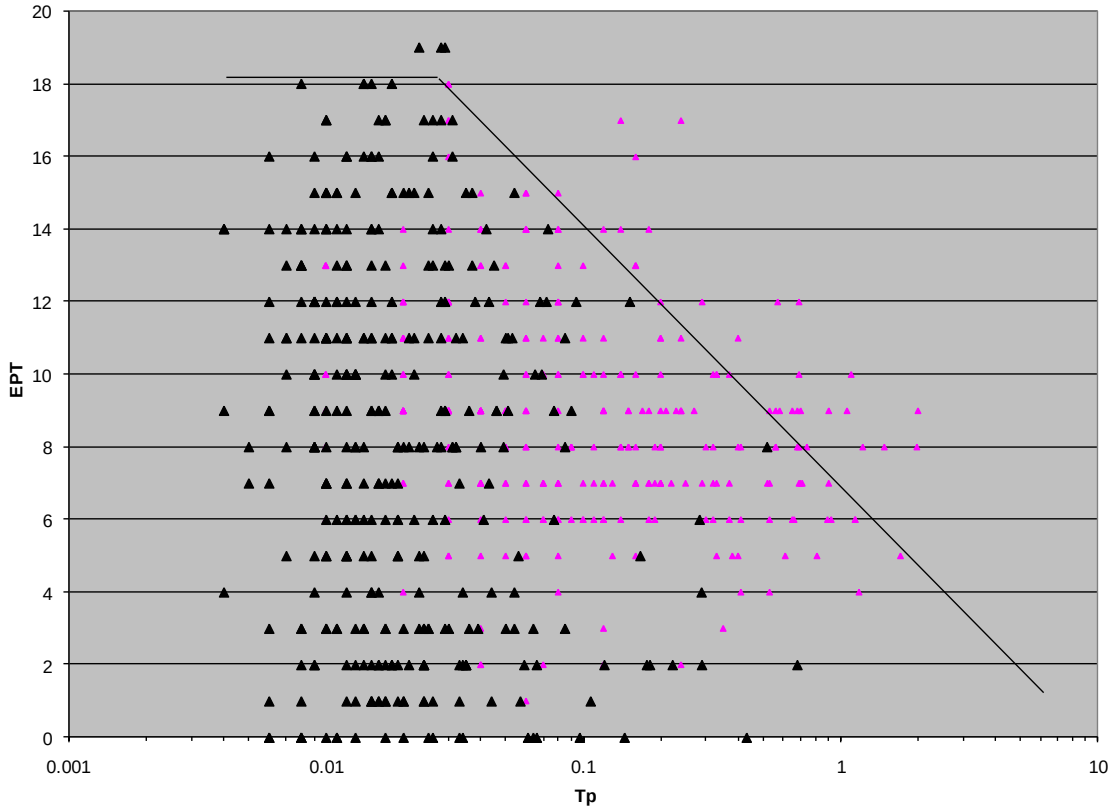


Figure 2 – USGS Chester Country data (pink triangles) replotted with MBSS data (black triangles) after rarefaction.

In this figure we include all the sites from the USGS Chester County study rather than the small subset of sites selected by Hall and Associates in the personally communicated figure to G. Fred Lee (see above). What is evident from the rarefaction exercise is even given the difference in sampling habitat and sampling design, rarefied samples fit within the wedge shaped plot identified in the original relationship (lines of Figure 2), supporting the original observation that taxa richness does, in fact, decrease with increasing nutrient concentrations and that this general decline begins at approximately 40 μg/L.

Methodological Differences Relevant to Application of Change-point Analysis and Conditional Probability

The second major problem with applying the Chester County-USGS data is related to study design requirements for the application of gradient based change point analysis. The USGS data used in this study did not incorporate low nutrient least disturbed reference sites into the study design. There are very few observations for low nutrient conditions, likely a function of there being substantially increased nutrients from wastewater discharges and agricultural land use in this region (Rief 2002a,b). In contrast, the MBSS data and the EMAP data used in the two endpoint determination reports were collected using probabilistic designs. They, therefore, represent the regional conditions most accurately. What these data indicate is that there are substantially more low nutrient conditions in this region than accounted for in the USGS Chester County study. There is a good reason for this – the Chester County –USGS study was not designed for this application, but rather had a very specific and targeted study question. It is impossible to predict what invertebrate metrics would look like if the USGS design had incorporated more low nutrient sites and their field methods were applied to those low nutrient sites as well, but we anticipate

that they would have encountered more taxa, including EPT taxa, in lower nutrient sites and that the resultant graph would mirror the ones generated from the MBSS Piedmont data. Because of the design limitations of the USGS data, it is inadvisable to apply change-point analysis to these data and we did not do so because of the lack of representative data. It is equally inadvisable to apply change point analysis to the mixed MBSS – USGS dataset again, because of substantial differences in study designs and sampling protocols.

USGS Report Conclusions Relevant to TMDL Effort

In relation to whether or not nutrients are causing a substantial degradation of aquatic life in these streams, it is interesting to note that the same studies cited by Hall via personal communication to G Fred Lee (see above), the data of which were the basis for Figure 1, conclude the following:

> "Overall, analysis of the sites in the Delaware River Basin by the U.S. Geological Survey, in cooperation with the Chester County Water Resources Authority, indicates that from 1981 to 1997, the sites affected by wastewater-treatment discharge have improved water chemistry and benthic-macroinvertebrate communities indicating better stream quality. Although improving, **these sites remain substantially degraded because of heavy nutrient loads that are negatively impacting the biological, chemical, and physical properties of the streams**. Sites not associated with wastewater-treatment discharge indicate declining stream quality because of the unstable stream bottom and susceptibility to flow fluctuation, potentially from increased peak flows caused by urbanization." (Rief 2002b, p. 4)

It was the conclusion of the same authors whose data apparently contradicted our conclusions that, in reality, rather than countering the basis for the TMDL, actually reinforce the basis of the TMDL. Chester County Water Resources Authority and USGS conclude that sites in the County receiving wastewater-treatment discharge "remain substantially degraded because of heavy nutrient loads". Moreover, they note that improvements made by those plants in terms of nutrient reduction (principally for ammonia) have resulted in some improvements in benthic macroinvertebrate communities, suggesting further improvements might also reduce the degradation associated with the still "heavy nutrient loads".

REFERENCES

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